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THE

TREE-LIFTER;

OR,

A NEW METHOD OF TRANSPLANTING FOREST TREES.

BY

COLONEL GEORGE GREENWOOD.

HE WHO HAS PLANTED A TREE HAS SET THE ELEMENTS TO WORK FOR HIM.

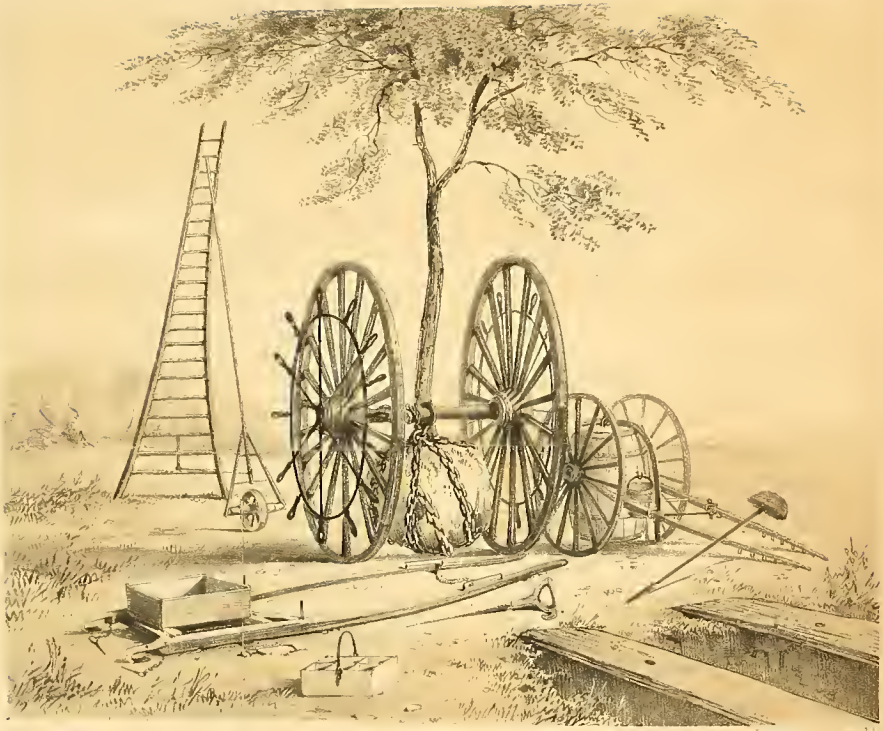
LONDON:

PRINTED FOR

LONGMAN, BROWN, GREEN, AND LONGMANS,

PATERNOSTER-ROW.

1844.



THE TREE LIFTER.

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LONDON:
Printed by A. SPOTTISWOODE,
New-Street-Square.

THE

TREE-LIFTER.

INTRODUCTORY.

Among the advantages of transplanting with the "Tree-lifter" may be reckoned its cheapness. Its simplicity is such that the whole may be performed, and even single-handed, by a common day labourer. One man may plant one tree per day, of from twenty-five to thirty feet in height. To transplant trees without the ball of earth requires great care, labour, and expense in tracing out the small fibres of the roots, which after all are nearly valueless. All transplanted trees are the better for being watered; but with the ball of earth this is by no means neces-

sary. To transplant without the ball of earth, and not to water, for at least two summers, is hopeless. This is a great expense, besides staking, and tying, which plants with the ball of earth do not need. The growth of trees transplanted with a ball of earth is not checked; but without a ball of earth, trees transplanted with whatever care, or at whatever expense, are checked in their growth for eight or ten years, and if they do not die, they become living scarecrows.

Over the nursery plant, as a single tree, the transplanted tree has the advantage of a start of from twenty-five to thirty years, besides saving the expense of the material, and carpenters work, for at least two fences for each tree.

The system recommended would have peculiar advantages for planting avenues.

DESCRIPTION OF THE TREE-LIFTER.

A pair of wheels eight feet in diameter, standing four feet six inches apart, or the same width apart as the common carts and waggons of the country. Twenty spokes. Width of the tire, two inches one eighth. The wheels quite straight, and *undished.* An iron axle of three inches diameter throughout, and perfectly straight. An iron wheel, fixed with a linch pin, on each end of the axle, outside the box of each wooden wheel. The iron wheels to have six spokes, ending in wooden handles projecting one foot beyond the rims. One wooden handle fixed on the rims between each spoke. The ends of these twelve handles to be just within the rims of the wooden wheels. The entire machine thus forming simply a windlass on wheels. A strong

iron ring playing loose on the axle, and a strong iron hook playing loose on this ring, to hold the weight when raised.

Shafts ten feet four inches from the axle ; to take on and off the axle by means of a hook and screw. Five chains twelve feet six inches in length, with a hook at each end ; one chain fourteen feet six inches in length, with a hook at each end, and with six round links at each end, to distinguish it from the other chains. A box with six compartments to hold the chains. Two strong planks eight feet in length, with a hole bored in each, to fit on to a pin on the shafts, along which, and across the axle, the planks are to rest when carried on the machine. A box or thill on the shafts to carry four blocks for the wheels, spades, pickaxes, &c. A South American surcingle, and three or four rope traces with a hook at each end. A strong rope

to be attached by one end to the axle.

At the other end a strong iron ring to receive the chains which encircle the ball of earth, and to be attached to the hook and ring on the axle, when the weight is raised.

DESCRIPTION OF THE PRUNING SAW, AND PRUNING LADDER.

The best instrument to prune trees with is a carpenter's *turning saw*, with coarse teeth, set wide for the purpose. Having a large handle, with a hook to attach it to boughs or the rounds of a ladder, and admitting of the blade being taken in and out by screws, and replaced when broken. The saw is held by the round part of the handle while sawing a branch from below upward; and all branches should, if possible, be begun

from below, to avoid tearing the bark and last layers of wood as the branch falls. A chopping instrument, such as a bill-hook, besides bruising and splitting the wood, is apt to cut too close, or not close enough. In the first case, the parts are injured from which the new healing growth is to proceed; in the second case, a dead stump is left to be enclosed by the annually increasing stem, which is probably rotten before it is enclosed. Besides, a chopping instrument is not adapted to getting between branches to thin them out. These saws will pass between branches which are too close better even than the knife. One of these blades fixed on a light rod is the best instrument to clear leaders which cannot be reached with a knife or a hand-saw. In this case, work the saw in a line with the stem of the tree; not across it. These saws may be bought at Coleman's, cutler, Haymarket.

The pruning ladder should be triangular; that is, to the Kentish fruit ladder, wide at the base and narrow at the top, should be added a single prop. The lower end of the prop should diverge into two branches, to receive a wheel like that of a wheel-barrow. When lowered, the ladder is placed and wheeled on this prop. When reared, the prop being attached to the ladder by a rope, it is pulled towards you by raising the ladder by one of its lower rounds. If well made this ladder is perfectly wieldable, and safe at the height of upwards of twenty feet. The ladder is easily detached from the prop, and used singly, if required.

DESCRIPTION OF WATER-CASK.

I have found the following sort of water-cask very useful:

A pair of old gig wheels, four feet

in diameter. A thirty-six gallon cask, thirty-two inches high. Swing this cask between the wheels by two iron arms, fifteen inches of the cask above the arms, seventeen inches below them.

An iron handle to pass over the top of the cask, and sufficiently free from the cask to allow of its being tilted. The handle to take on and off the axle with a hook and screw.

A pair of old gig shafts to take on and off the handle.

A leathern hose, with wire inside, at the lower part of the cask, just long enough, when turned over the cask, to reach the bottom of it on the other side. The hose to take on and off with a screw. A lid, opening with folding flaps, fastened by a bent hasp, which will pass over and secure the hose while in movement. A couple of leathern buckets. A hook before and behind the cask, to carry the buckets.

A wrought-iron bowl, to lade with.

This cask may be used either by hand, or with a horse, or donkey. It may be locked going down hill, as recommended for the "tree-lifter."

According to circumstances, or the power of approaching the tree, the hose or the buckets may be used, or the cask may be tilted.

PRACTICAL PART OF TRANSPLANTING.

Choose a tree of from twenty to thirty feet in height, with several leaders, or with some unduly large branches. Prune the tree previously to digging round it, so as to take from the head at least as much as will, in all probability, be taken from the root, not by *cutting in* the head and branches of the tree, but by giving it a clear leader, and cutting out all branches large enough to compete with the stem,

low enough to be reached by cattle, or the growth of which is vertical, or parallel to the stem. Cut all close to the stem. Dig a trench round the tree, at the distance of about twenty inches from it. Undermine the ball of earth, at the depth of about three feet, so that every root may be cut previous to lifting it. Tie some old carpeting or matting round the stem of the tree. Place the machine, without the shafts, on the planks, and block the wheels; the centre of the axle over the centre of the ball of earth, and the ring of the windlass rope at the foot of the tree. Place the chain with the round links horizontally, and loosely, round the lower part of the ball of earth. Cross the end held in the left hand twice over the end held in the right hand, and lay both ends down. Pass one of the other chains, as far as its middle, through the ring of the windlass rope. Pass the ends of this chain beneath the horizontal chain, and hook the ends back

on the chain itself. Do the same with the four remaining chains. So that when the windlass is worked these five vertical chains, being at equal distances from each other, shall bear an equal distress from the weight of the ball. Fasten the horizontal chain, by hooking it to any convenient part of the vertical chains. Raise the ball of earth with the windlass, and place the ring of the windlass rope on the hook attached to the axle. The ball of earth carried thus is pressed together by the chains acting towards one another, and the greater the weight the greater the inward pressure. A ball of earth resting on a sledge or truck soon shakes to pieces on the least movement, besides the difficulty and mischief done in lifting it on and off the truck.

The tree is lowered into the pit prepared for it with the same facility as it is raised. If it does not stand upright it is easily raised by the windlass, while

earth is cast under where it is wanted. The unchaining is only reversing the enchaining. If during the carriage, owing to wet or the friability of the earth, the chains cut into the ball, and the load sinks, it is easy, by letting the load down altogether, to take up and tighten any one or every one of the chains.

Place the upper surface of the ball of earth at precisely its former level, and do not cover it; but raise a ridge of earth round the outside of its circumference, so as to form a *pan or irrigation cup.* Tie some bushes round the stem to prevent cattle from rubbing it. The organisation of the bark is easily destroyed by any bruise, or by cattle rubbing against it. It is the common error to believe that the bark is *poisoned* by the oil from the skin of cattle.

It may be found necessary to stay the sway of the tree while in movement, by ropes from the stem to the shafts.

In going down steep hills the machine may be held back by a horse ridden behind, and hooked on by the South American surcingle and single trace; or the machine may be very conveniently blocked by lashing a bar of wood across the shafts, close in front of the wheels, and taking out the screw which fastens the shafts to the axle. The horse will then bear back against the wheels instead of against the axle, and the friction against the wheels will increase or decrease directly as the downward impetus.

The principle of locking two-wheeled carriages by creating friction on the wheels induces a slight downward pressure on the horse's back. But the long shafts act as a lever in the horse's favour, and the extra pressure on his back is not to be spoken of in comparison with the labour of bearing back a loaded cart.

THEORY OF TRANSPLANTING. OUTLINE OF THE PHYSIOLOGY OF TREES AS REGARDS TRANSPLANTING, PRUNING, &c.

The supply must be equal to the demand; if not, scarcity will ensue. He who expects that a diminished root will support an undiminished head will be disappointed. This is the fundamental principle of transplanting. And in transplanting, the head must be curtailed exactly in proportion as you expect to curtail the root.

With the exception stated below, trees imbibe from every part of them which is exposed to moisture, and give off (transpire) from every part of them which is exposed to drought. The root is the part which is constantly exposed to moisture, and which furnishes the constant supply of sap to the tree. That part of the root which is universally believed to imbibe

no moisture, the woody part, is the only part which does imbibe moisture; and that part of the root which is universally believed to be the only part which does imbibe moisture, the unripe ends or fibres, is the only part which does not imbibe moisture.

That trees imbibe from any part which is exposed to moisture is evident from the growth of cuttings, which have no root, old or young.

In the hot climate and on the arid hill-sides of Spain the olive is propagated by cuttings. These cuttings are old branches seven feet in length. One end of such a cutting is buried about eighteen inches in a pit, and concrete earth or clay is raised, like a pillar, around it, so that, at the upper end, only about eight or ten inches of the cutting is exposed to the atmosphere. Thus excretion of moisture is prevented, and secretion of moisture takes place, throughout about six

feet of the cutting. In the course of two or three years the pillar of earth is gradually taken away; when a head has grown on a trunk five or six feet from the ground.

Most plants which will strike from cuttings will grow whether the proper end of the cutting is placed upwards or downwards. Some plants will grow if the head is placed in the earth, and the roots in the air. In this case, the former head throws out roots as a cutting does, and the former root throws out branches as roots often do suckers. It is an error to suppose that the *old* organisation either of the actually existing head or root can change; though the *new* growth in diameter of both will doubtless be reversed; and in process of time the old roots should be encased in stem wood, and the old head in root wood. The internal structure of such a plant would be worth examination.

If the centre parts of slips of currant

bushes are placed in the earth with both ends out they will absorb moisture, strike root, and grow. If a long vine branch is coiled round the inside of a flower pot, and covered with earth, as it is ten times as long below the earth as a common cutting, it will shoot with ten times as much vigour; and if heat is given, it will bear fruit the first year. I attribute this to its greater quantity of wood exposed to moisture, and its consequent greater power of absorption; though it may be attributed to its greater space for throwing out side fibres of roots. From these facts I have no doubt that there is a side (lateral vascular) communication, both for absorption and exudation, from the heart wood, through the bark, throughout the whole extent of the roots, stem, and branches of trees; also, that the sap will flow in the heart wood either upwards or downwards, that is, either from the head towards the root, or from the

root towards the head. I found by experiment, in 1832, that the roots of birch will bleed either upwards or downwards; and if a root of a birch is cut across near the stem, so that it cannot absorb moisture itself, it will bleed freely from the stem.

These facts are at least sufficient to prove that the woody parts of trees imbibe without the aid of the small fibres or ends of roots. From the following experiments, also, I am satisfied that roots do not imbibe at all from the small mouths (capillary stomata), or from the small sponges (spongioles), which are *supposed* to exist at their ends.

In March 1836 I made some horse-chesnut seeds grow in water, in my barrack room, and found that when the root was cut off when it was several inches long the plant would still grow, and would continue to throw out fresh roots as fast as they were cut off; but if the plant was divided from

the seed, by cutting the *umbilical bands*, it died, though the root was perhaps twice the length of the plant; yet when the seeds remained attached to the plants till the roots had become woody, the plants grew for years. I imagine that the elaboration of the sap is entirely in the seed, and passes through the umbilical bands, for the growth of the plant upward and of the root downward. These umbilical bands pass one to each cotyledon of the seed, in dycotyledonous plants. They may be considered as the stalks or petioles of leaves; and in reference to a theory of Priestly's, that plants derive their nutriment from the air through the medium of their leaves, it may be stated that the cotyledons themselves may be considered as leaves, and indeed in many plants actually become what is called hypogeal, that is, they rise above the earth into the air, and are converted into what are called

the seed-leaves; but, I imagine, not before the root is capable of absorbing and of transmitting moisture to the plant; certainly the cotyledons of the seeds of trees, full as they are of stored food, will not nourish their seedlings without a supply of water as well as air. I have known four cotyledons in a seed. In this case twin plants arise. The first side fibres or shoots which are developed on the roots of horse-chesnuts grown in water are regularly arranged in six vertical lines along the root.

As long as the root is unripe, in other words, unwoody, it is wholly useless; that is, it has no upward conduit for the sap. The small fibres of the root bear the same relation to a tree as children to a commonwealth; so far from being a present source of strength, they are an actual expense and outgoing, though, by their growth and maturity,—that is, when the

unripe fibres become woody roots, and the children become men,—they are the very springs of vital energy.

Particular stress is laid on these doctrines, because they account for the free growth of a transplanted tree when the small fibres, or ends of its roots, are all cut off, in contradiction to the universal vulgar error that trees absorb moisture only from the small mouths or sponges at the ends of their roots. If it is answered, that the roots of these transplanted trees, and the cuttings, absorb only from their ends which are cut, and that in the case of the olive branches the pillars of earth only prevent transpiration, I must confess that the theory is possible, but think the reverse most probable. And how have the cuttings absorbed whose ends were out of the ground?

The upward course of the sap is through the whole woody part of the roots, stem, and branches of the tree. This woody

part has been hitherto divided by physiologists into two parts, the heart wood or dead wood, and the alburnum or unripe, and outside rings, or latest deposits of wood around the stem. It was considered that the heart wood really was dead wood, and that the upward course of the sap was through the alburnum, or latest rings of wood only. In March 1832 I remarked the stems of some birch trees, which I had cut down in the previous November, bleeding from the heart wood. I was not then aware that Coulon had about this time observed the same thing in cutting down some poplar trees in France. I afterwards satisfied myself, in various ways, that the whole of the wood is the conduit for the upward course of the sap.

In April 1832 I found a birch tree in Dyhrram Park, of from sixty to seventy years growth, which had a large scar from injuries from cart-wheels. The

scar might have existed from fifteen to thirty years, being perfectly indurated, and in parts turned to touchwood. I tapped the scar in the centre with a very large gimlet. I had not pierced an inch before it ran freely while boring. I bored about three inches in depth. The tree was about nine inches through, in the direction of the bore. The dead surface wood was perhaps a little more than a quarter of an inch in depth. The dropping was so frequent as almost to amount to a stream. This could only have flowed from the heart wood; since no alburnum, or new wood, had been deposited on the scar for about twenty years.

After the ascent of the sap, it is supposed to be elaborated in the leaves, and in descending between the wood and the bark, to deposit the annual ring of new wood or alburnum round the branches, stem, and roots, and also to furnish the new growth of the roots in length.

There is a wide difference between seeing and foreseeing a result. Yet when facts and results are shown us, how often do we imagine that we have foreseen them. I would not undervalue the magnificent advances of modern science; but, certainly, hitherto, in vegetable physiology and agricultural chemistry, science, far from directing us, has been contented dimly to shadow out theories to account for the facts and results which practice has ascertained. And these theories every day changes for new ones. Is it that a whole life is necessary for the acquirement of science, and a whole life to make practice perfect, and that the two weapons can never be wielded by one hand? That Liebig should reproach gardeners and farmers for not being chemists, is about as reasonable as if they were to reproach him for not being a gardener or a farmer. He who is wiser than his neighbours had better enlighten, not abuse their darkness.

What theorists call the prejudice of practical men is not so obstinate but what it will learn if they can teach it any thing to its own interest. "Physician heal thyself." The conceit of the closet can only be cured by practical out-door proof. When chemists make their fortunes as farmers or gardeners, farmers and gardeners will follow their example. In the meantime those who have to *do* cannot afford to spend a life in labour, the product of which is a doubt.

According to an experiment of Hales, which has been since verified by others, the sap rises with a force sufficient to support the pressure of a column of water of double the height which would burst an ordinary hogshead cask. And we see that it ascends to prodigious heights, yet we are ignorant how, or from whence, it is first absorbed, and we are ignorant of the *mechanism*, that is, of the cause and laws, by which it is forced up.

We see the miraculous and universal system of transubstantiation with which we are surrounded in the vegetable world, yet we are not only ignorant of the *chemistry* which produces it,—which, from absorbed moisture and gases, forms all the various woods, bark, leaves, flowers, scents, fruits, seeds, &c. of that most exquisite kingdom,—but we are even ignorant in what part of the plant the elaboration takes place, or from what part of the plant the new growth is deposited.

Whether any chemical change or elaboration of the sap really does take place in the leaf I shall not question; but I think that possibly the leaf only gives off the supernumerary watery parts necessary to take up and conduct to their destination the carbonic acid, ammonia, and inorganic matters requisite for vegetable life, and that it exhales the unnecessary gases, &c. after the decomposition of the constituents absorbed from the soil. Certainly the

transpiration or giving off of water from the leaf, when exposed to drought, is very rapid, and the communication from the root to the leaf very rapid and constant; since on felling trees of thirty or forty feet high, while they were shooting in the summer, I have observed the shoots lose their turgescence, that is, droop, in the course of a few minutes from the time that the stem is divided from the root. The accurate and admirable Hales found that a sunflower, in dry, hot, weather, gave off two pounds and a half, that is, two pints and a half of water in twelve hours. At night, and in moist weather, the quantity was much less. Senebier supposes that plants give off two thirds of the water which they absorb.

Many physiologists imagine that the great use of the leaf is to *absorb* moisture. M. Bonnet tells us that the leaf is formed to absorb, chiefly from the lower part, because dew ascends. But as dew is a condensation of moisture sus-

pended in the atmosphere, it cannot be said to ascend more than to descend; and the physiologist forgets that rain descends. But I do not think that M. Bonnet's facts are more to be depended on than his reasoning. He states, that if leaves are floated on water on their upper surfaces they will die as soon as if they were not put in water, but if they are floated on their lower surfaces they will remain alive as long as if their stalks were immersed in water. I tried this experiment in 1836, and found that the leaves floated on their upper surfaces remained alive as long, or rather longer, than those on their lower surfaces; one remained in part alive for six weeks. I have only had opportunity of seeing these theories of M. Bonnet quoted.

According to this class of physiologists, of which the great chemist Liebig is the modern oracle, when trees are in full leaf they receive their entire nutriment through their leaves from the atmosphere, and "the

complete dryness of the soil" would not then injure them. If this were so, when trees were cut down at Midsummer, till the fall of the leaf, the heads would remain alive, and the roots would immediately die. The reverse of this is the case; the roots remain alive, and shoot out without any assistance from the atmosphere, and the heads immediately die.

It is certain that great chemical changes or elaboration of the sap must take place in the root or stem before it reaches the leaf; since sap of very different qualities is drawn from the stems of different trees. Witness the sugar from the maple and birch, the resin from the fir, &c., &c., which are found in the heart wood. Also the alteration of the heart wood in density, and the change of alburnum into heart wood, argue elaboration in the stem and deposit from the upward sap. This opinion also seems to be supported by the fact, that when a peach is grafted

on a plum stock, &c., the new growth in diameter on the stock is still plum, which it would not be if the new growth was entirely derived from the peach leaves, or even if it was entirely elaborated in them, and entirely deposited from the downward sap; while, on the other hand, if the elaboration was wholly in the root or lower stem the wood and leaves of the peach would become plum. But purple beech and variegated sycamore grow for ever unchanged, though engrafted on common stocks, as a single branch of a plant accidentally variegated will for ever retain its character. This looks like local elaboration.

I think it possible that engrafting trees on stocks of minor growth may incline them to fruit instead of growth, on the same principle as ringing branches or tying ligatures round them does. In each case the natural supply of sap is diminished.

The upward growth of a tree, as com-

pared with its downward growth, may be said to resemble the growth of animals, by *intus-susception;* that is, the growth of the shoots of the current year of the leader and branches is a growth or extension of parts already formed, by the upward and outward increase of all those parts from within. Besides the growth at their ends, all the parts of the shoot of the current year, to a certain degree, grow bodily upwards, or by what may be more properly called intus-susception. I have observed this in plants which I had introduced through the window-sill, and trained against the shutter, by marking the position and upward progress of the stalk of each leaf where it joins the stem. Duhamel first pointed out this fact. With the exception of the parts of the shoot of the current year, no other part of a tree makes any upward progress.

The downward growth of a tree, that is,

the elongation of the roots and the growth in diameter of every part of the tree, may by comparison be said to resemble the growth of minerals — by *juxta-position;* that is, roots are lengthened only by the deposit of new growth at their ends, and they do not progress bodily through the earth. I have never remarked accurately how this is in plants grown in water; but I believe it to be the same as when they grow in the earth, and that this mode of growth is the result of the organic structure of the root, and not of the mechanical difficulty of forcing itself through the earth.

It has been hitherto held that the stem, branches, and roots grow in diameter by the deposit of new growth on their outside, and that there is no increase from within of their internal parts.

Is it possible that the growth by intussusception, or by juxta-position, may be dependent on the presence or absence of the

pith, since the roots of dycotyledonous plants, (plants whose seeds have two cotyledons,—I know of no easier language,) which may be said to grow by juxtaposition, have no pith? In their stems and branches, which grow in diameter in the same way, the pith is *supposed* to be dead and functionless; but in the shoot of the current year, which may be said to grow by intus-susception, the pith is a most prominent feature, and apparently full of vitality and vigour, and the woody monocotyledonous stem (the palm, the yucca, &c.), whose growth in diameter is entirely and permanently by intus-susception, may be called one entire and permanent column of pith.

Duhamel thought that the last year's layer of bark was converted into the this year's layer of wood. We can *see* that this is not the case. Du Petit-Thouars thinks that the new layer of wood is formed by the buds (though I believe the *origin* of this theory

is due to Darwin); that the fibres are the roots of the buds, which, at the bursting of the buds, run between the last year's bark and wood to the ends of the roots. Those who can assent to this theory may flatter themselves that they know something of the growth of trees in diameter; those who cannot believe it must confess their ignorance on the subject. To say that the new layer of wood is formed from the viscid substance to which Grew gave the name of *cambium* does not remove the difficulty. Whence is the cambium itself formed? How and where elaborated; how organised?

Dutrochet and Link bring us back to Hales's doctrine of the all-importance of the pith. Indeed Dutrochet would establish the *omnipresence* of the pith. He tells us that each division between the annual layers of wood is a pith for the layer outside it; and that, in addition to the original medullary rays, which run from

the central pith to the bark, and which are annually prolonged through each successive pith and layer of wood,—in addition to these, intermediate medullary rays are developed from each new pith, which run from that new pith to the bark, and are annually prolonged.

This growth sideways, between the medullary rays, is doubtless the mode in which alburnum is converted into heart wood, and heart wood increases in density. It must be from the upward sap; and from examination of branches which have been rung, I have much reason to believe that the alburnum below the rings is thus converted into heart wood. This growth may be said to partake of the principle of the growth by intus-susception. One cannot, however, suppose that this new growth in the comparatively hard alburnum is from the roots of the buds, according to Du Petit-Thouars's system. I have remarked, that when firs are cut across,

they bleed only from these rings of pith; and I *think* I have remarked this in birch trees. These rings of pith are probably the main if not the sole conduits for the upward sap, which from them and the medullary rays exudes sideways, and, through the medium of the intercellular passages, is possibly elaborated in the vessels, tracheæ, and cellular tissue; but probably all external parts of plants are capable of transpiration or absorption, according to circumstances, as well as of inspiration or expiration. Happily, however, in a sketch of this sort, we are not called on to unravel the mass of contradictory theories and *facts* of the microscopic observers of the vessels, cellular tissue, stomata, &c., of the woody layers, leaves, cortical layers, and epidermis. This mass of contradiction has been accumulating and entangling itself from the time of the admirable Grew and Henshaw, who originated this species of anatomical re-

search on the completion of the microscope by Hook, to our own time, that is, to the time of the equally admirable Dutrochet.

The medullary rays, which appear like the spokes of a wheel, when the stem is cut across, are in fact thin plates, running the whole length of the stem, roots, and branches. They are supposed by Dutrochet to be of the same nature as the pith, though they *appear* very different. In width, they increase each year by the width of the new layer of wood, across which they extend to the bark; and in length, they increase each year by the length of the new shoot of the branches and roots.

The medullary rays and the concentric rings of pith form interstices in the wood, and prevent its perfect union. What are called *shakes* in timber arise in them. These *shakes* are often seen *outside* the stems of living oaks. They are the consequence of diseased medullary rays; they

proceed horizontally from the centre of the tree, often run to a great extent vertically, and are never cured.

I think that the medullary rays may be *seen* to prolong themselves into the latest layers of bark if the stem of a living oak tree is cut across; at least there is a white line across these layers opposite the end of each medullary ray. If these lines are prolongations of the medullary rays they probably play a prominent part in the deposit of the new layer of wood and bark; at least these prolongations must of course remain for ever, and the new growth, both of wood and bark, must be deposited between them. These white lines across the new layers of bark may, however, be only organs of elaboration or of respiration, or conduits for absorption and exudation. If they are not in unison with the medullary rays, at least the commencement of each white line corresponds exactly with the termination of

each medullary ray. The new medullary rays proceeding from the new rings of pith, first remarked by Dutrochet, may be easily seen in oaks; they may also be seen to begin from the new layers deposited outside the ends of dead branches.

The root has as strong a first tendency downward as the stem has upward, though it puzzles our philosophy to account for either. The first downward tendency of the root is, however, soon counteracted by circumstances, such as the necessity of atmospheric aeration, the goodness of upper compared with lower soils, the intervention of rocks, chalk, &c.; and the root is found to grow horizontally, or sloping upward or downward, according to the inclination of the ground. I consider the idea of the tap root of the oak as a vulgar error. I have never seen any trace of a root at any great distance from the surface of the ground, nor do the stumps of oaks,

when grubbed, show any symptom of a tap root more than other trees.

The celebrated Duhamel, wishing to protect his field from robbery from the roots of a row of elms, cut a deep ditch between the elms and his field. The roots, however, were not to be done. They of course followed the surface of the ground, whether down, horizontal, or up hill, and took the ditch "in and out clever" into the philosopher's field. Duhamel thinks these were very cunning roots, and that they had an instinctive notion of the treat they were to have on the other side of the ditch, and grew *at* it. Had the philosopher built a wall in the ditch, and then filled it in, he would have beaten the roots, on account of their inability to leave the surface and get under the wall.

Were we to add one step to the beautiful theories of Knight and Dutrochet respecting the growth of *adhesive* plants,

and the tendrils of climbing plants, *from* the light, we might almost attribute the upright growth of the stem to the mere swelling (turgescence) of the cellular tissue of the new green shoot, and its aberration from the perpendicular to the effect of light on the swelling.

It is asserted, on microscopic observation, that the bark of all new green shoots is entirely composed of two layers of cellular tissue. The cells of the outside layer of tissue decrease in size from within outwards; the cells of the inside layer decrease in size from without inwards. Thus the largest cells of each layer are next one another, or in the middle of the bark, and the smallest cells are on the two sides, that is, the outside and inside of the bark. Owing to this formation, swelling would stretch a slip of bark perfectly straight, since each layer of tissue would tend to curve itself outward. But in plants which grow towards the light the inside layer of

tissue is the thickest, and therefore the most powerful in its action, consequently swelling would bend a slip of such bark inwards or towards its shoot, and such a shoot would be held up by the inward pressure of its bark all round it, as a wall may be propped from both sides. But in the bark of plants, or parts of plants, which grow from the light, such as ivy, the tendrils of climbing plants, &c., the outside layer of tissue is the strongest; and the tops of the shoots of such plants tend to stand upright by the pulling outward of their bark from all sides, like the mast of a ship. But light, by increasing the giving off of water (transpiration), decreases swelling, and when it falls unequally on plants, the forces on the illumined side will be weakened, and the shoot, according to the formation of its cellular tissue, will be turned either towards or from the light. Thus ivy, or the tendrils of climbing plants, are turned from the light towards

any opaque body, while the generality of plants are turned from the opaque body toward the light. The whole of a plant kept in a room will grow towards the window. But though this principle is not so striking out of doors, it is perpetual and universal.

As the light falls equally on the leader of a tree it goes up straight. In proportion as it intercepts the light from above, the branches grow towards the light at the sides; and if one outstrips its neighbours, the light from above turns its end up. If the lower tier of branches outgrows the tier above it, in turning up, it will take its neighbour with it. That tier will turn the tier above; and so in succession all the branches will grow upward. This growth is often seen in beech trees.

It is this principle which prevents the boughs of a tree from growing against one another. In proportion to their opacity they grow one from the other.

Notwithstanding the original downward vertical determination of the root, and upward vertical determination of the stem, the annual vertical growth in elongation of a tree, either upward or downward, is nothing in comparison with the growth of it, which forms angles with a vertical line: that is, out of all the numerous points of elongation of the head of a tree, there is but one which can go vertically upward in continuation of the line of the stem; and out of all the numerous points of elongation of the root, there is but one which can go vertically downward in continuation of the line of the stem; and I believe that one ceases to do so very soon.

If the leader of a tree is killed, the light falling equally from above on many buds a multiplicity of leaders may be developed; though if one grows more vigorously than the others, by overshadowing them from above with its own side growth, it will force them to grow sideways to the light, and

the tree will again become single-leadered. Without pruning, a tree may become round-headed from the merest accident; for instance, an insect, or a bird, or the wind destroying the top bud. A tree on the side of a steep hill may be seen to grow from the opaque side above it, and, after it has reached a certain height, to curve back again.

So far light would appear to be the principal agent in directing the growth of plants. Yet it is said that if beans are planted in holes through the bottom of a box filled with earth, the stems will grow upward from the light into the earth, and the roots downward towards the light into the air; and the plants will perish when they cease to derive nutriment from their seed-leaves or cotyledons. Nay, so determined is the downward tendency of the root, that when I have inverted a newly-grown bean in water, so as to have the roots in the air, covered with a dark cup,

the existing ends of the roots, not the new growth, have all turned short downward toward the light, and that not from flaccidity or drooping. And even in the denser medium of water, if the end of a root is accidentally turned upward, its new growth will immediately turn perpendicularly downward.

And, from an admirable experiment of Knight, both the ascent of the stem and the descent of the root would appear to depend on gravitation; for when he subjected growing beans to a horizontal centrifugal force superior to gravity, their roots grew from, and their stems towards, the centre, and the whole growth of the plants was horizontal. But, suppose this to be so: *why* the root should obey, and the stem disobey, the otherwise universal law of gravitation, would still puzzle our philosophy, as I said before. I have hitherto been unable to get a copy of Mr. Knight's work, and

only quote his opinions as quoted by others. I regret this, as, from them, he appears to be the most acute of all physiologists.

That the growth in the girthing or diameter of trees is a downward growth, that is, from the descending sap, seems clear from this:—If a ring of bark is taken off round the stem or branch of a tree, so as to intercept the return of the sap between the wood and the bark, as long as the tree or branch lives it will continue to increase in girthing or diameter above the ring, but not below it; and when such a branch is sawed in two, lengthways, each additional annual layer may be counted above the ring, but none below it. But if the growth in diameter was deposited from the upward sap, the parts of a branch below the ring would be more favourably situated for it than the parts above the ring.

A new innermost layer of bark (liber)

is also formed each year, from the descending sap, corresponding with the increased diameter of the tree. The old or outward layers are stretched outwards, crack, and form the rough bark seen on old trunks. The yearling shoot has but one layer of bark, the two-year old shoot two, and so on; and each shoot may be said to have as many layers of bark, as well as as many layers of wood, as it is years old. But with regard to the layers of bark, besides the sloughing off, the circumference of the earlier layers would be very disproportioned to that of the later ones. If the circumference of the bark of the seedling oak was half an inch, it would make a poor show on the outer circumference of a full-grown tree, supposing it to have existed. This growth of the bark may also be considered as partaking of the principle of the growth by juxta-position, since the annual new layer is a distinct

coating or deposit of new growth on the inside of the bark, and not a growth or increase of parts already formed. It is from the downward sap, since in branches which are rung it ceases to be deposited below the rings, but is continued annually above the rings.

De Candolle makes a distinction between the outer skin or covering of the leaf and annual shoot and that of all other parts of the tree. He calls the outer covering of the leaf and annual shoot the *cuticle*, and that of the rest of the tree the *epidermis*. There is certainly a difference between living skin and bark and dead skin and bark, and it might be as well if they had different names; but if we give the name of cuticle to the outer covering of the living bark, it will be found, with its green under layer of parenchyma or "herbaceous envelope," to extend over a much larger space of our forest trees than De Candolle assigns to it. There is nothing

in which even the same sort of trees differ more than in this respect. According to growth, soil, exposure, &c., the cuticle exists to a very indefinite period; and it would be hard to say where cuticle ceased and epidermis began. Living external bark may be found on oak, ash, beech, Spanish and horse chesnut, sycamore, poplar, &c., &c., on parts varying from twenty to fifty years in age. On roots also of the same age may be found a fine silvery cuticle which tears off like paper; though in roots, under ordinary circumstances, the under layer is white, not green.

De Candolle states it as a distinctive characteristic of roots, as compared with the stem, that "they do not become green even when they are exposed to the air and light." And this opinion is universally held by physiologists; but it is an error. De Candolle, in proof of the opinion, states that the roots of

hyacinths grown in transparent glasses do not turn green. This is true of them, and also of the silver ends of woody roots; but it must be recollected that to neither of these can the air be admitted when they grow in water, or light when they grow in earth. It is however, I believe, true of both these, under any circumstances. But when part of a woody root is accidentally exposed by the wearing away of a bank, &c., the layer below the outer cuticle will be found green, precisely the same as on a branch, though where the root goes under ground, both nearer and farther from the stem, the under layer will be white. The layer under the outer cuticle may also be observed green at the commencement of the root when it is accidentally exposed near the neck of the plant. This is not a matter of opinion, but a matter of fact, and we have only to use our eyes to see it.

Each layer of bark is supposed to have

its proper pith or cellular ring outside it. The green cellular or "herbaceous envelope" under the outer cuticle is supposed to be the pith of the outer layer of bark, and to be to the layers of bark what the central pith is to the layers of wood; and throughout its whole extent there is probably a direct vascular communication between this green external pith of the bark and the internal central pith of the wood, by means of the medullary rays. This green *parenchymatous* pith of the bark is in communication with and is in fact a continuation of the *parenchymatous* parts of the leaves, (the spongy porous parts, as distinguished from the woody fibrous parts,) as the outer cuticle of the stem is of the cuticle of the leaves and buds.

All physiologists talk of the *circulation* of the sap; and the expression must be used, though it is a very incorrect one; that is, no one, I believe, has asserted, nor

can we suppose any one to imagine, that there is a *true* circulation of the sap of plants, like that of the blood of animals. By the circulation of the sap is meant merely its *ascent* through the wood into the leaves and buds, thence into the green outer pith of the bark, on which the leaves and buds are situated, and its *descent* to the roots, through the rings of pith of the bark. How the descent dies off and stops, it is difficult to imagine; but it is still more difficult to suppose that any part of the sap should *re-ascend.* The whole affair, however, is a matter of the merest conjecture. And the fate of the physiologist is to build theories whose very data are doubt and difficulty.

The "*proper juices*" of plants are found in this green "herbaceous envelope;" for example, resin in the fir; and the woods of different trees do not differ more in their proper constituents than the barks of different trees; and, *possibly*, as the first

herbaceous envelope is burst and destroyed the next ring of the pith assumes its functions. Indeed in the plane tree, whose epidermis or outer bark sloughs off as it dies, a green outer layer is found to the very foot of the largest trees, doubtless owing to the free admission of light and air. *Possibly, also,* for the deposit of the new external layer of wood and of the new internal layer of bark, it may be necessary to bring together, through the medium of the medullary rays, on the common ground on which the two layers are deposited, and on which these rays of the wood and of the bark meet, if not join, juices the product of chemical decomposition, assimilation, and elaboration in the stem from the upward sap, which have been subjected to respiration and transpiration in the leaf, and to all these processes in the descent of the sap through the bark.

Let the practical man guard these

external piths from external injury. Besides the gnawing of horses, cattle like to find soft-barked trees, such as Scotch firs, &c., of a size that they can take between their horns to rub their foreheads against, and do infinite mischief in this way. Trees that are too large for this are comparatively safe, as the side rubbing of cattle does not injure them so much; besides, that the dead epidermis of old trees is a great defence to them.

That the growth of the root is from the descending sap seems clear from this, that if the stem of a tree is rung at any part between the root and the branches, so as to intercept the sap returning from the head, the tree will die, unless branches shoot out below the ring, whose descending sap nourishes the root.

In July 1832 I observed a horse-chesnut tree near Esher, in the corner of a field adjoining Sandown turnpike-gate. It had

been barked by cattle all round, I should suppose twenty or twenty-five years before, since the surface of the barked part was rotten, and might be picked off. Mr. King, steward to Mr. Spicer, to whom the tree belongs, said that he had recollected the tree in this state for eighteen years.

The head of the tree was in full foliage, and at the end of some branches, which had been cropped by cattle the previous year, had shot six or seven inches. The girth of the barked part of the stem was thirteen inches and seven eighths. The girth below the barked part was twenty-two inches and a quarter, and above the barked part, twenty-nine inches. The tree had ceased to deposit new growth on the old scar, which I attribute to the rottenness of the surface of the scar, and to its having mouldered away from under the living bark. I think it probable that if a new surface was veneered over the old scar

the stem would continue to deposit new growth on it from above. This tree is still alive,—1844.

I imagine that the reason that this tree has continued to live is, that each year it has shot out new branches from below the scar. These branches have each year been eaten off by cattle; but they have elaborated and returned sufficient sap to nourish and to keep the root alive. I imagine that if these branches had been allowed to grow they would have taken so much sap that it would have ceased to be forced up the old stem, and that the old stem would have died. But the existence of this tree and of rung branches proves to ocular demonstration that the sap goes up the heart wood, since on the scar and on the rings no new wood or alburnum is deposited. It is true that the number of rings of what is called *sap wood* or alburnum differ in different trees, and even parts of the rings of a tree may ripen sooner into

heart wood than other parts of the same rings, so that on the same transverse section of a tree there shall be more rings of sap wood on one side than on the other. This may be observed in oaks; but on the scar of this tree no alburnum or sap wood has been deposited for upwards of thirty years.

As the roots of trees grow in length through the earth they are in perfect contact with it, and as they increase each year in girthing or diameter this contact is continued, and the pressure against the earth even increased. I imagine that this close contact of the roots with the earth is very essential for the absorption of moisture; and that when a ball of earth is taken up with a transplanted tree, the parts of the roots contained in the ball are infinitely more efficient for the supply of sap than five times their length of root not in perfect contact with the earth. But certain it is, that, by taking a large

ball of earth, with " the tree-lifter," I have transplanted trees of about twenty-five feet in height in *every* month in the year, without a single failure, and without the plant feeling its removal so much as a greenhouse plant does potting, that is, without a single leaf drooping, even in the hottest days of June, July, and August, though the plant was unwatered, and with the same growth on the tree, in the next and following years, as on those in the plantation from which it was taken.

I consider, however, that the worst time to transplant a tree is when it is shooting; the best time as soon as possible after it has shot; that is, as soon as it has formed its winter bud. This will differ in different trees. Some are fit to transplant in June, or even in May. The best months for transplanting the generality of English trees with the ball of earth, are July, August, and September; for though the

upward growth has then ceased, the growth in diameter, and the downward growth, that is, the elongation of the roots, is in the fullest tide.

From observation of the growth of the root in potted plants, and also of the seedlings of trees grown in water (one of which I have in its seventh year's growth), I am satisfied that the great downward growth of the root takes place immediately after the great upward growth of the head; that is, at the end of summer, during the autumn, and in early winter; and that the wounds of the roots of trees, transplanted immediately after they have made their upward shoot, heal or cicatrize, or, as the gardeners say, *callous over* immediately. These *callouses* are a prolific source of new shoots for the root, which besides, from having been shortened, makes a profusion of lateral shoots that same season. These shoots become woody, and

the root is consequently in a state to supply the great upward demand next spring.

We may convince ourselves by experiment, that the downward is after the upward growth of trees. If notches are cut on the stem of a tree from the root to the setting on of the first branches, the new growth over the scars will be when the tree is ceasing to shoot. The upper notches will heal first, in the form of a horseshoe, with the heels downwards, that is, the growth will be on the upper part and the sides of the notches, without any growth from the lower parts of the notches. This fact also strongly corroborates the opinion that the new growth in diameter is from the downward sap; for if it were a side deposit from the upward sap the lowest notches should heal first. I have found that if stems thus notched are inverted, the new growth comes only from the sides

of the notches, and neither from the upper nor lower parts of them, which I am unable to account for. But the notches nearest the head are the first to heal, and those nearest the root the last to heal.

The new growth on the notches will be free in proportion as they are in the line with large branches above them; and I imagine from this, that though the returning sap from branches deposits round the whole stem, it deposits most freely on the proper side of the branches; and the larger annual deposit found on the *outsides* of the outside trees of plantations, which has been attributed by Duhamel and Buffon to their having their largest roots on that side, is, I have no doubt, the result of their having their largest branches on that side. An exposed tree standing singly will throw out its roots equally all round it; but the new layers of wood round the stem will be much the largest on the leeward side,

because the largest branches are on the leeward side; yet if the upper part of one half of the side of a stem is dead, the opposite living side will deposit round the whole living part below. And I imagine that it is thus that the windward roots of an exposed tree are nourished by the descending sap from its leeward branches.

As far as I have remarked, though young roots are round, the older ones greatly incline to the oval shape; and in all the transverse sections of roots which I have examined the *eccentricity* of the common point from which the (*medullary?*) rays diverge, and which is occasioned by the comparatively over-growth of the upper sides of the new annual rings, is very striking. May this be from the descending sap having a greater facility of depositing on the upper sides, or from the roots meeting with a less mechanical resistance from

the earth on the upper sides? The largest growth on branches is on the sides on which they have the most spray or small twigs; so that branches which grow diagonally upward, having the greater quantity of spray on the outside, on account of the greater quantity of light, will also have their annual rings of wood largest on the outside from the descending sap of the spray depositing most freely on its own side.

But the stem of a tree will be exactly like a river; its size will depend on the number and size of the branches which fall into it; and it will be seen to increase below and to decrease above the spot where each of its branches join it. It is beautifully ordained, that no branch can grow above without depositing below strength to support itself.

Fir trees, which are very regular in the size and position of their branches, are also very regular in the tapering of their stems;

but if the lower branches are cut, or killed by their neighbours, in the course of time the branchless part of the stem loses its tapering form. And the stem of any tree which has been long bare of branches shows like the Lower Nile,—unvarying in size, because without a tributary. It will appear to the eye as large above as below; for as regards the horizontal girthing, the head deposits equally down the whole extent of the bare stem below it; that is, though the over deposit of growth from over large branches on their own side of the stem may tend to make the stem oval instead of round, this will make no difference to the comparative horizontal girthing of the tree at different heights. And if equals are annually added to unequals, though the original absolute inequality will for ever remain the same, the relative inequality will annually decrease; and the stems of trees which have been long branchless

may be found of nearly the same girthing for fifty or sixty feet in height. If the yearling shoot is one inch in diameter and the two-year old shoot two inches in diameter, the girthing of one will be double that of the other; but if each shoot increases annually one inch in diameter, the proportion of their difference alters the first year; that is, the girthing of one, instead of being twice as large, is only one third larger than the other; and when one girths ten feet the other will girth ten feet one inch, which is in effect no difference at all. To grow valuable timber we should not only aim at a maximum height of branchless stem, but a maximum head on a maximum height of branchless stem; for in proportion to the quantity of head will be the quantity of its downward deposit, or increase of the diameter of the stem.

Against the theory of the one vernal ascent and the one autumnal descent of the sap, and in favour of the constant cir-

culation, or at least constant supply of sap, we must consider that boughs even of considerable thickness, cut off in the autumn, will become dried throughout before the spring. But what can account for the moisture of boughs, and even the most delicate spray, exposed at great heights in the air, but the constant supply of sap?

Indeed, if the first theory were correct, there is no reason why plants should not live through the winter out of the ground, and plants taken up in the autumn should grow as freely when again put in in the spring as if they had just been taken up. The contrary of this is the case; the roots of plants taken up in the autumn, as well as the plants themselves, soon become dry. Why? Because the roots are deprived of the power of imbibing moisture.

I have observed that if the stem of a young tree grown in water is cut at the beginning of winter, the root immediately ceases to grow; doubtless because the stem

is necessary to return the sap to nourish the root. If this theory is true, coppice-wood, hedges, and shrubs which are intended to shoot up again, should be cut at the end of winter,—not at the beginning of winter. If they are cut at the beginning of winter, the transpiratory parts of the plants in the air are disproportioned to the absorbent parts in the earth, and the circulation and elaboration of the sap is injured through the whole winter, till the plant can shoot out again in the spring. I imagine that this circulation and elaboration do go on in the winter; that, in the early part of winter, actual new growth of the root is often going on; and that, during the whole of winter, the new growth is solidifying and becoming woody.

I consider it a proof both of the existence and of the necessity of this winter circulation and elaboration of the sap, that shrubs which are headed at the

beginning of winter are very liable to break out; they then suffer much from the frost. When I have cut down sycamores in August, of about twenty years growth, I have known them make this unnatural effort to relieve their roots from *suffocation;* and I have observed the leaves on the shoots which they have then thrown out green to the middle of the succeeding January. Plants which do not ripen their wood, and which are annually killed in parts by frost, such as fuchsias, verbenas, &c., should not be cut till the frost does come; they should then be cut *immediately.* This not only gives the last chance for the ripening of the roots, but if the plants are cut earlier they are very liable to break out, and then suffer from frost.

I do not believe that the sap ever ceases to circulate; but the tide is perhaps at its lowest ebb in January, and that is possibly the best month for felling timber. Timber which is felled at the high tide of

sap and growth is extremely liable to fermentation and decay.

It is a dangerous experiment to cover up the roots of trees. Their chief duty appears to be to absorb moisture in the soil; but atmospheric aeration is necessary to them, and under the eternal agency of physical causes, acting probably on the peculiar structure of their cellular organisation, the roots of each tree grow at the level best adapted to them, and to the offices which they have to perform. This should not be interfered with. If dressing is laid on the roots, it should not be deep, or of a nature impermeable to air. Trees which have had their roots deeply covered up languish and die, unless they throw out a new set of roots above the old ones which have been smothered; but, generally, the new tier of roots is not strong enough to supply the exhaustion of the old head.

Liebig tells us that the presence of oxygen, — consequently of atmospheric

air,—is necessary for the generation of carbonic acid from the humus in the soil; and that from carbonic acid plants assimilate their carbon (which, loosely speaking, the whole of the tree may be said to consist of), by decomposing the carbonic acid, and giving off the oxygen. I should consider this as the cause why roots keep within the reach of atmospheric aeration, since the main article of the food of trees is found in that district; though Liebig follows Priestly, Senebier, and De Saussure in thinking that after the first infancy of the plant, that is, after the development of leaves, it is indebted to the atmosphere only for the supply of carbonic acid. But can we doubt that the chief growth of plants (I speak of dicotyledonous forest trees) is from constituents absorbed from the soil, not from the atmosphere, when we see the perpetual difference of growth of the same plants in the different soils of the same parish; that

is, in the same atmosphere? The cactus is quoted by Liebig, Richard, &c. as thriving on the driest soils, by deriving its nourishment from the air, independent of its root. Yet Lucas informs us, that "a cactus planted in a mixture of equal parts of charcoal and earth throve progressively, and attained double its former size in the space of a few weeks." This must have been from the soil, not from the atmosphere.

Liebig supposes plants to assimilate their nitrogen by decomposing ammonia, stored in soils from rain water, manure and humus, and giving off the hydrogen; their hydrogen by decomposing water and giving off the oxygen. Carbon, nitrogen, hydrogen, and oxygen, with certain peculiar inorganic matters absorbed from the soil, are the sole constituents of plants. Indeed all organic existences, that is, the endless varieties of the animal and vegetable kingdoms, are composed of

these four elements alone. These four elements are contained in carbonic acid, water, and ammonia. Throughout all organic nature, during life, combination from the constituents of these three goes on, and after death the decomposition of those combinations into the constituents of these three. That is, carbonic acid, water, and ammonia furnish the constituents from which, by combination, result all the exquisite living forms which we admire and love; and into these three those forms are by decomposition eventually resolved. Throughout the realms of vitality the actual living are the late dead freshly combined; and from the decomposition of one generation of plants and animals the recomposition of another generation results.

I should doubt the supposed excretion from the roots of substances unnecessary to the growth of the tree. If this were

so, the roots would soon be surrounded with such substances, and would be incapable of absorbing nutriment. In chalk districts eternal woods are found composed of nothing but beech; in other soils, of nothing but oak. The oldest vineyards and the oldest hop-gardens are the best. (I say nothing of old meadows, since trees are in question.) In all these cases, if the roots excreted substances unfit for nourishing the plants the whole soil would have become saturated with them. Land plants grown in water are always unhealthy. Under these circumstances, may not colouring matter, or other substances supposed to be excretion, be the result of disease and decay or partial maceration of the roots. There is no discoloration of the water in which the seedlings of forest trees are made to grow.

I imagine that the roots of trees, in absorbing the moisture with which they come in contact, give off the unnecessary

parts of this by transpiration in the air. I do not perceive what should cause roots to transpire when surrounded by moisture, or if they do, they must return, like the dog to his vomit, and again absorb their own transpirations.

If it were owing to the poisonous excretions of the roots that the same crops cannot be taken year after year from the same land, this cause would apply equally to all lands; but some soils are known which return the same crops incessantly.

It is perhaps possible that the reason why each plant appears to have its favourite soil is, that it finds there in the greatest abundance the particular inorganic matters adapted to its peculiar structure; that the reason why particular plants will not grow in particular soils is, the absence of the particular inorganic matters adapted to their peculiar constitution; and that the reason why particular plants *cease* to grow on particular

lands is, their having abstracted those peculiar inorganic constituents necessary to them,—not their having deposited a suicidal poison from their roots, and thus forming cases of vegetable "felo de se."

The organs of absorption of the roots of wheat, beans, potatoes, turnips, or mangel wurzel, cabbage, and lucern or sainfoin, probably differ as much as the internal and external structure of the roots and plants; and, besides, searching for their inorganic constituents at different levels in the soil, they may probably be only capable of taking up those adapted to their peculiar constitution.

In farther reference to Liebig's opinions, that the proper juices, the various peculiar acids, and the organic salts, found as carbonates in the ashes of plants, and formed by the combination of the alkaline bases, potash, soda, lime, magnesia, with the peculiar organic acids of plants, play an essential part in the functions

and development of the different parts of plants, cannot be doubted, though we are quite in the dark about it. And as regards the peculiar inorganic matters absorbed from the soil by particular plants, while the land is bearing one sort of crop it may be lying fallow, and collecting them, by disintegration, for another sort.

I believe Sir Humphry Davy first remarked, on the assumption that the upward and downward growth of plants is vertical, that woods and crops growing on the side of a hill would derive no greater advantage from the additional space than if they grew on the horizontal surface of its base. But it must be recollected, that as the plants on the side of a hill rise tier above tier, with the same light and aeration from above they have a greater side light and aeration; they are in fact placed head above head, like people in a race stand, where but for this arrangement the *spectators* would have good opportunity for

looking upward at the roof, but none for looking sideways at the race. But the merit of this principle is very apparent in the step stands in green-houses; though probably the origin of these stands may be, the greater facility they give to see and to water the plants. But if the plants stood on the area of the base of the stand each would be shaded all round by its neighbours, and would receive light only from above. The base of what is called in Hampshire "a hanger," or a hanging wood, would not support as many trees with as full heads as stand on the hill side. Let us conceive these —

Densas, umbrosa, cacumina, fagos —

to be sunk vertically downward from their beautiful gradations till their roots shall stand on the base of the hanger; the long one-sided columns of green will be submerged, smothered, and killed below the one common level of the tops, and

the plants will be deprived almos entirely of their organs of respiration and transpiration.

But besides this greater space for the heads, as the roots follow the surface of the earth, plants on the side of a hill have a greater space for their roots than if they had only the base of the hill side to grow on. In reference to an entire hill of a given base, this increase of surface or space for the roots will be not only directly as the height of the hill, but also directly as the steepness of its sides. Taking one side of a hill, if the side forms an angle of forty-five degrees with the horizon, its additional surface or space for roots, as compared with its base, will be as the diagonal is to the side of a square.

We are not to expect that trees drawn up in the interior of sheltered plantations, and transplanted to exposed situations, will grow. If we could move a cube acre

of ground with a young tree, from a sheltered to an exposed situation, the plant would dwindle and decay. A tree grown in an exposed situation contrives by degrees to shelter itself; that is, it grows to leeward of itself; for the windward growth diverts the current of wind, and *throws it up.* And we see, in exposed trees and woods, that they get taller by degrees from the windward to the leeward side. The chief injury which trees suffer from wind is while they are shooting. If the weather is calm while they are shooting, they will make a year's growth upward, and to windward; but their general growth will be only upward, and to leeward; not from being *bent* by the wind that way, but from all other growth being destroyed while the shoots are tender. Plenty of examples of this sort of growth may be seen in the neighbourhood of the sea. This is from the mechanical force acquired

by the wind in passing over the uninterrupted surface of the sea. It is common to attribute the blasted vegetation of trees in the neighbourhood of the sea to the saline or chemical qualities of the sea breeze. If it were so, the growth would not be hurt more on one side of the tree than the other, for the atmosphere on one side of the tree must be as much impregnated with salt as on the other. If it were so, trees would grow as luxuriantly on the south-west side, and on the top of Mount Edgecombe, as they do on the sheltered north-east side, for the chemical qualities of the atmosphere must be the same in each place. If it were so, we should not find the same sort of scarecrows on our inland bare plains and heaths. In a bare open country we have only to see on which side of a tree is the lowest and shortest growth of its head to know where the south-west is; and if the stem of such a tree is cut across,

the largest sides of the annual rings of wood will be found on the north-east side.

If it is attempted, by pruning out the leeward growth, to give exposed trees straight leaders, or to force them to grow to windward, they will decay, from want of head to return sufficient nourishment to the root; though, if it is gradually done, trees may be very much *helped* on this principle. Firs, being essentially single-leadered trees, and not having the reproductive powers of deciduous trees, stand wind very badly. It is the common error to believe that they will stand exposure well, because they are found high up mountains; but this is only where they are sheltered by the mountain *side;* and they will not bear well the exposure even of our low bare plains, still less of the *tops* of very moderate hills.

In the shelter of woods, from want of room for their roots, and from want of all

side boughs, trees in general grow weakly, and do not attain their maximum height in a minimum time, if ever. On the other hand, single trees, which have plenty of room for their roots, from exposure, or from the quantity of light all round them, generally go more to side branches than to height; but in sheltered situations, with good soils, I have no doubt that, by early and gradual pruning, single trees might be trained to much greater heights than we see at present. Doubtless in ornamental grounds every variety of growth should be encouraged; and doubtless any variety of growth can be attained by gradually and constantly cutting out all growth except in the direction desired. To prove this, we have only to observe our wall fruit trees, and the forms of animals, arches, &c. into which trees are cut. In trees, whether for beauty or profit, no attribute is more to be admired or desired than height. In pruning to this end the

rules are simple, and they are applicable alike to the nursery plant and to the largest timber tree. Keep a clear leader. Cut off all branches large enough to compete with the stem, or which grow parallel to it. Shrive the stem up one third of its height. Cut all close to the stem. With the above exceptions, a tree cannot have too many branches, as the returning sap of each contributes to the growth in diameter of all that part of the stem which is below it, and to the growth of the root both in length and diameter. But pruning, like thinning a plantation, cannot be too gradual. It should be annual.

In counties where it is the practice to shrive the hedge-row trees, their branchless stems are ascended by means of spikes at the sides of the feet. In the East, palms are ascended, to inoculate the flower and to gather the fruit, by placing the feet against the stem, and the back against a

band which encircles the stem and the climber.

A branch, as long as it is alive, does not form a knot in timber, but only a cross grain; that is, as the stem increases each year in diameter it encloses each year a portion of the root of each of its branches, and the grain of these branches forms, of course, an angle, more or less acute, with the grain of the stem; but if the branch dies the stem encloses each year a piece of dead wood instead of living wood, and as the bark then ceases to *run*, very frequently the bark is enclosed with it. This forms a knot, instead of a cross grain, in the timber; and as the dead wood is dry when it is enclosed, the living wood, when sawed up, dries from it. This forms a moveable knot. But, besides the flaw in the timber, the dead wood which is enclosed forms an impediment to the course of the sap, as

much as if a bolt of iron was passed into the tree.

De Candolle remarks, that as the diameter of the branch is at first extremely small, but increases annually, each year the stem encloses a larger circumference; and that part of the branch which is enclosed is in the form of a cone, its base at the bark, and diminishing inward towards the pith. The outer part of the branch is in the form of a cone, its base at the bark, diminishing outward. This is very ingenious; but no such actual internal cone exists. The medullary rays and longitudinal woody fibres of the new annual growth of the branch are prolonged, and run vertically down that part of the stem of the tree which is below the branch; so that it is only the grain of the centre part of the branch which runs across the grain to the centre of the tree. It then runs down the

stem of the tree to the roots. The grain of every other year's growth annually turns down the stem of the tree, short of the centre of the tree, directly as the newness of its growth. The same or rather the reverse *appearance* may be observed above the branch if the branch and the stem are cut longitudinally where they join; that is, the grain of each year's growth of the branch *appears* to turn *up* the stem of the tree; for each annual downward growth of the branch meets the corresponding annual downward growth of the head of the tree, joins or anastomoses with it, and passes round the side of the branch down the stem. Thus, above, and below, and on the sides of the branch, each annual growth of the branch and of the stem are not two growths, but one growth, and it cannot be said where the growth of the branch ends and that of the stem begins; and the part of the branch within the stem is much more

like the roots of a tree than a cone. The internal cone, so ingeniously *imagined* by De Candolle, would only exist if the annual downward growth in diameter of the branch ceased when it arrived at the stem. Thus a branch unduly large in proportion to the head of the tree will form from its own deposit an excrescence below it where it joins the stem; and a dead branch, or an undersized branch, overgrown by the head of the tree, will cause a hollow below it, from stopping the downward current from the head, which cannot turn sufficiently short to deposit immediately below the branch. This is often seen in beech trees; and the groove is sometimes prolonged the whole extent of the stem.

When a living branch is cut off a vigorous tree close to the stem, new growth, both of wood and of bark, is gradually and annually deposited over the end of it. This new twin growth begins

in a semicircular form on the top and sides of the scar, till the growth from one side meets the growth from the other side at the lower part of the scar; the growth then proceeds towards the centre of the circle; and as the new annual growth both of wood and bark is deposited on the top as well as the sides of this circular *wave* of growth, it keeps pace with the level of the annually increasing diameter of the tree, and when the ring closes in the centre no indentation is left; and each succeeding year the new annual ring of wood and of bark is deposited over where the branch was, with as much regularity as on any other part of the stem. The end of the branch will die, and dry to about the thickness of paper; and a very slight and inconsiderable flaw will remain in the timber, where the living wood is deposited on this dead surface The healing takes place in like manner over a dead branch which is cut off. But

if a dead branch is left till it becomes rotten where it joins the stem, as there is no firm surface for the deposit of new wood, a hole remains in the stem of the tree. In this the water, running down the stem, lodges, and saturates the parts. This, with the action of the oxygen of the air, continues the process of decay, which is communicated by contact to the heart wood of the tree. This is the fruitful source of destruction to our timber trees, to the life of which, otherwise, there is apparently no necessary limit. Very little care may avoid this chief cause of decay.

What is called *snag* pruning may be defended so far as this,—that if the snags are left sufficiently long to remain alive, a cross grain only is continued in the increasing stem, and the diameter of this cross grain does not increase so much each year as if the head of the branch existed, but, owing to the overshadowing

of the head of the tree, the snags almost invariably die, and rot into the stem of the tree.

If trees are left so close in plantations as to prevent the growth of all side boughs, or to cause the gradual death of those that are developed (which fills the timber with long dead knots), owing to the small head, the deposit and growth in diameter of the stem, and also the whole growth of the root, will be very slow and slight. Weak poles will be reared, which, when the plantation is thinned, will be liable to be blown down, or to break out all over the stem from the admission of light. This causes a severe check to the growth of the head, and such trees are liable to become stag-headed. Exposure is no excuse for not thinning plantations. There is no reason, because the heads of trees are exposed to wind, that their roots should be robbed by their neighbours, and starved by their own want of head.

The largest *sound* tree I have ever measured is "the grindstone oak" in the Holt Forest. It is thirty-five feet in girthing at three feet from the ground. It is dead, and was apparently *lately* dead when I first saw it, since the bark was still on it. I think it has been originally a *pollard* (*polled* or headed); and the largest sound timber I have ever seen in England has been old pollards, allowed to grow up in our forest grounds, after the pollard system had ceased. They were probably allowed to grow because, being many-headed, their timber was not valuable.

The great secret of large timber is centuries of non-cutting down, good soil, room, and sheltered situation. These conditions rarely come together in cultivated countries, though they do sometimes in our old family places. The free growth and the enormous measurements of trees in the forests of uncultivated countries

are more frequently to be attributed to the concurrence of the favourable conditions above stated than to the peculiar attributes of the trees themselves. Such trees, when imported, and planted on the poor soils and exposed situations which are alone planted in cultivated countries, make poor progress, and never reach any size.

I have received the following marvellous measurements of some pinus lambertianas on the Columbia, from an authority that I cannot doubt. At eight feet from the ground they were fifteen feet in diameter. The stems were branchless to two hundred and fifty feet from the ground, and were there thirteen feet in diameter. If the new annual ring of wood was a quarter of an inch wide trees would attain this diameter in three hundred and sixty years; and supposing them to have grown a foot a year in height, this would allow them eighty feet of head

above the branchless stem. That trees of gigantic stature are not more frequently found in unappropriated forests is generally to be attributed to their want of room; that is, to their growing so close as to injure or kill one another. They cannot attain to first rate growth without ages of contention, and killing all their neighbours. In doing so, the growth of the survivors is not only delayed for centuries, but in general permanently marred. The axe *should* gradually and successively relieve them from their neighbours.

It is a great mistake of De Candolle, Richard, and other French writers, to lay down the branchless stem as a distinctive characteristic of a tree. All trees which grow singly on sheltered lawns have branches down to the ground, and from the lowest parts of their stems; and most beautiful objects they are. The branchless stem is the result of injury from the hand

of man, or beast, or neighbouring trees. If there is an exception to this rule, it is the Italian pine.

Trees which are valueless as timber, such as pollards, and which therefore escape the axe, I believe continue to exist for centuries, perhaps for thousands of years, even after they are hollow. The old pollards which grace our forest grounds and commons were probably headed as young trees, and their growth cut periodically, as our underwood is now, the browsing of the deer and cattle necessitating in such places this sort of aerial coppice-wood. However the heads of these may be lopped, every year of life adds one ring of new wood and bark to the girthing of the stem. The same takes place when the tree is perfectly hollow. The inside dead wood being dry and unporous prevents the bleeding or efflux of the sap. I have found the girthing of some of these relics of the olden time much greater than the

girthing of any sound timber I have ever measured, though probably the pollards never girthed large as sound trees. Even when the circle is broken, and they stand like detached strips of bark, the new deposit of wood and bark takes place on their outside, while their inside is sloughing or rotting off; and these detached strips gradually, and annually, progress outwards from what was the centre of the tree.

Of course, all side or lateral growth is, from the position of its weight, more liable to break than upright or vertical growth. When a tree takes two leaders, from want of light and from want of room on the inside, the leaders grow from one another to the outside, and from their weight inclining to the outside, without any thing to balance it on the inside, they are liable to split from one another. As each leader enlarges annually in diameter, the junction at their two bases progresses upwards, en-

closing the bark of each between the two. This prevents the deposit of any new wood on those parts of the inside of either leader, and consequently also prevents the perfect junction, or anastomosing of the wood of the two leaders. Besides this, water lodges in the hollow at the fork; and a frost which is severe enough to freeze this water will rend apart the trunk of the sturdiest oak to a certainty.

Early and constant pruning will avoid the cause of these fruitful sources of decay in timber.

If the heads of trees are dying in, from accidental blight, or from the destruction of their leaves and shoots by a strong south-wester, or from frost, &c., in all cases they should be cut in, not only to where the boughs are alive, but to where they are vigorous, and, if possible, at the foot of a living twig. If the dying boughs are left on the tree, the sap goes up them, without the power of breaking out or

returning, consequently the roots are starved.

If the dying boughs are cut off, the sap, which would have been uselessly expended in them, bursts forth in the form of new shoots, and, in returning, contributes to the growth and nourishment of the roots. In such cases, trees are often killed by being left "to see where they break out." They should be cut immediately. Bis dat qui citò dat.

If the branches are not cut at the foot of a living twig, their ends should be again cut off at the foot of the new shoot, in order that its descending sap may deposit wood and bark over them. If long stump ends are allowed to remain, they rot before the new growth in diameter of their stock has enclosed and covered them.

Near natural ponds, where the whole soil holds, the presence of trees is beneficial, from their prevention of evaporation, and from the condensation which takes

places in moist warm weather, particularly on smooth barked trees; but near artificial ponds or dams no growth whatever should be allowed. Roots are the great creators of leaks; nor should they be allowed on masonry. If stone is bored, the bore plugged with dry wood, and the wood then soaked with water (no matter by which end, as regards the grain, the water is imbibed), it will burst asunder the most solid rock, such is the resistless force of turgescence or swelling; and this force is probably a main agent in raising the sap to the enormous heights which it attains. Roots act on this principle, and they will rend apart the strongest masonry, or lift any weight of stone. In Greece, Italy, and throughout the East, roots are the great dilapidators of the ruins of antiquity. We may observe the effect of a too sudden exposure to the opposite force of drought in the *warping* and rending asunder of the strongest woody organisations.

In the present rage for pinuses, I should like to say a word in recommendation of the deodara cedar and of the araucaria imbricata. They are both perfectly hardy. The deodara is from the Himalaya mountains. It attains the largest growth, and is perhaps the most exquisitely graceful of all trees. With us its growth appears to be about twice as quick as the common cedar in the same soils. The araucaria is the only hardy timber tree we have of a really tropical character. It is from the Andes, and attains an enormous size. Like pinuses, these trees should be planted out early, when they are from six inches to a foot high. The best way to rear them as single trees in parks, &c., is to trench a pit of five feet in diameter; to put a triangular fence round them of about four feet high, made of poles, the thinnings of plantations, driven into the loose ground so close one to the other as to prevent sheep browsing the plant, splayed out-

ward, bound together with bars at the top, and with cross bars over the top. This is not only hare proof and cattle proof, but man proof, wind proof, and frost proof; and it does not give a greater degree of shelter to the plant than is necessary to one of that size. When the head of the plant emerges from its fence, place a single hexagonal post and rail round it, to keep off horses and cattle, but under which sheep can pass. It is true that these close fences discourage the free growth of the lower side branches; but it must be recollected that these branches must eventually be taken off, on account of the cattle. This should be done gradually. And when the branches are out of the reach of sheep, the inner fence may be removed, and the stem bushed. The side branches above the inner fence must also be taken off by degrees. But the plant should not be shrived up to "*the browsing line*" till it is three times

as high as that line. The outer fence may then be removed, but the stem kept bushed. If the side branches are taken off by degrees, the sap which would have supplied them increases the growth and vigour of the remaining head; but if they are too suddenly removed the plant will break out all over, or it will be starved, from want of head to elaborate the sap and return it to the root. With the exception of one at Kew Gardens, Dropmore, the planter's Athens, has the earliest araucarias planted in England, and I believe it has the first deodara.

I conclude by recommending the *practice* of transplanting with the ball of earth, without reference to the *theories* with which it has been supported. Indeed, with regard to them, I do not believe that in all vegetable physiology or agricultural chemistry there is one principle to be depended on. In fact, the last science is a new light to us, for the first glimmerings

of which we are indebted to our immortal Davy. I say this with the deepest veneration for the brilliant talents and undaunted perseverance of those who have devoted themselves, or who still do devote themselves, to sciences of the first importance to the existence of man and the honour of his Creator; and with a heartfelt disgust at those who, pluming themselves on their progress in lower but more certain science, presume to taunt with their want of success philosophers who have attempted a labour, perhaps superhuman, —to throw light on the hitherto impenetrable darkness which has enveloped the processes of vitality,—to delineate the actually progressing operations of the hand of the Almighty in his noblest, most finished, most complicated works.

ADDENDUM.

After the paragraph ending "the parts of a branch below the ring would be more favourably situated for it than the parts above the ring," *page* 49, *second line from bottom, add,*

A slight deposit of new growth may be observed on the lower scar or lip of the wound of a branch which has been rung. This, I imagine, should be attributed to the descending sap already in the bark. And, from the same cause probably, if the branchless stem of a young larch tree is sawed across at the height of a foot from the ground in the spring, granulations of new growth, and a slight new deposit, will be formed around the stem, between the bark and the wood, during the summer. I at first mistook this new growth for a deposit from the upward sap; but after the first summer the new growth around a stem which cannot throw out branches ceases, and the stem dies. The death of

such a stem is *possibly* not merely the result of want of elaboration of the sap, but of want of sap to elaborate; for the communication is cut off between the wood, the conduit of the upward sap, and the bark, the conduit of the downward sap; and even supposing the bark without leaves capable of local elaboration of the sap, which is very probably the case, under the circumstances no sap would be supplied to the bark to elaborate. *Possibly*, *also*, this is the reason why the stump ends of branches or stems which have been headed die down to the highest shoots. I have known a decapitated beech stem lie dormant for a year, that is, make this slight new deposit the first summer, throw out branches the second summer, and continue to live.

The *descending* sap in the bark of the stem can, however, to a certain extent, *ascend* in the bark of the branches, and deposit new growth around them, as the

ascending sap in the wood can descend or bleed backwards. This is seen perpetually where branches are cut off at the distance of an inch or two from the stem. Their diameter will be enlarged each year, their ends cicatrised from the sap of the stem, and a protuberance will remain; and this makes evident the *unity* of growth which must exist at the foot of each branch, even with the part of the stem above it. The distance to which the descending sap will ascend the descending conduits of the bark of another branch or stem will depend on the strength of the tide. The most remarkable case of it I ever saw is at Warwick Castle, on that one of the two magnificent cedars between the castle and the river which is next the mill. A branch of about a foot in diameter (I write from recollection) has been cut off at the distance of about eighteen inches from the stem. The descending sap of the bark of the stem has ascended the whole distance on the upper side of this twigless and leafless

snag or stump end, and is cicatrising, or depositing new growth over the flat surface. On the lower side of the snag the new growth has reached only to within an inch or two of the end; and in increasing the diameter of the branch has separated the bark from the wood by about an inch. I imagine that this snag will eventually rot, and occasion the death of the tree; but that if it were cut off close to the stem the scar would be soon cicatrised over. It is a vulgar error to suppose that cedars will not bear pruning; they will cicatrise over the scars from the loss of large branches more quickly and more surely than any other tree. I should have stated elsewhere that perhaps the best time for pruning is when trees are in full leaf; they never bleed then. I have known sycamores and walnuts bleed when pruned at Christmas.

But as the new growth in diameter below the scar of branches which have been rung always ceases, though the branches continue to live, and to increase in diameter

above the scars, the descending sap would appear to be necessary to this new growth, if not its sole cause. And in speaking of the growth in diameter of the entire tree, I have taken this *fact* for granted, though this, like most other physiological *facts*, is a possibility based on probability.

I have observed larch poles, when nailed as rails in the air, without any communication with the earth, throw out twigs the first summer. This would appear to be the result of the elaboration of the upward sap already in the *wood*.

If a piece of bark is insulated, new growth will be deposited from the scar of the *continent*, but not from the *island*, except a very slight deposit the first year from the descending sap already in the bark. But if the island has a twig or branch on it, or if it throws one out, which is very likely, the descending sap from the branch will deposit new growth on the scar round the island. We are to suppose the upward sap

from the wood of the stem passes up the pith and wood of the twig or new branch into the stalky parts of the leaves and buds, thence into their spongy porous parts, and descends thence through the bark of the twig to the island of bark. Grew shows us that the vessels (the tracheæ) of the wood are prolonged into the woody fibrous or stalky parts of the leaves and buds.

I have no doubt that if ever so narrow an *isthmus* was left from the continent to the upper part of a branchless island, so as to convert the island into a peninsula, the isthmus would form a conduit for the descending sap from the continent, and new growth would be deposited round the whole scar of the isthmus and peninsula, as well as of the continent.

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